EITP30: Lab 2 - 2022

Juan Sanchez

For this second lab, we will deal with constructing the time-frequency structure of a synchronization signal burst (SS burst) and converting it to a time waveform. An SS burst in its simplest explanation, is an arrangement of multiple synchronization signal blocks (SSBs) confined over half a frame. We will only focus on the placement of the simplest and most important signals for the composition of the SSB, the primary synchronization signal (PSS) and secondary synchronization signal (SSS). However, remember that an SSB is also composed of the physical broadcast channel (PBCH) and its respective demodulation reference signals (PBCH DM-RS).

Pre-lab Section

As with the previous lab, we need some additional information to understand the next step in the creation of an SSB. We need to know in which indices of time and frequency to expect each of the components belonging to an SSB. Therefore, you should proceed as follows:

1. Please refresh Chapter 11 of the 4G book [1] and Chapter 16 of the 5G book [2].
2. Read 3GPP 38.211 [3], Section 7.4.3 (pp. 119-121).
    a. Optional: Read section 7.3.3 (p. 100).
3. Read 3GPP 38.213 [4], Section 4.1 (pp. 10-12).
4. Read 3GPP 38.101-1 [5], Sections 5.3.1, 5.3.2 and 5.3.3 (pp. 45-49)

Lab Programming Section

MATLAB will help us with the construction of the basic blocks for an SS burst. We should have a ready-to-use array containing symbols corresponded with subcarrier and symbol indices.

5. Download the MATLAB code on SSB generation from one of these options:
    a. Visit the webpage: https://www.mathworks.com/help/5g/gs/synchronization-signal-blocks-and-bursts.html. Then, run the following command on MATLAB's terminal: **openExample('5g/SynchronizationSignalBlocksAndBurstsExample')**. Work with the opened file for the laboratory.
    b. (Not recommended) The course content for Lab 2.
6. Read about how SSBs and SS bursts are generated on MATLAB's webpage.
7. The current code is generating an SS burst for a time configuration 'Case B'. Adjust the code, so that it generates an SS burst for a time configuration 'Case C', with numerology $\mu = 1$, for carrier frequencies within Frequency Range 1 (FR1) greater than 3 GHz.

Up to this point, we have managed to create the time-frequency section of an SS burst confined within half a subframe, as recommended by the 3GPP specifications. We now proceed to place the SSB burst content into a two-dimensional grid that represents the physical layer's available resources, where the axes are also subcarrier and symbol indices.

8. Consider the following parameters for the design of your code sections:
    a. Carrier frequency, $f_c = 3789.990MHz$
    b. Numerology, $\mu = 1$
    c. UE channel bandwidth, $BW_{ch} = 50MHz$
    d. Number of subframes, $N_{sf} = 5$

e. Normal cyclic prefix
f. Time-division duplex (TDD) mode
g. Operation without shared spectrum channel access
h. Offset from carrier frequency to SSB, $f_{Off,SSB} = 570kHz$
i. Offset from first time sample to SSB, $N_{Off,SSB} = 0$

9. Design a code section that can place the generated SS burst into the physical layer grid given by the design parameters.
    a. Hint: The FFT size and the sampling frequency can be known from the channel bandwidth and the subcarrier spacing.

With our physical layer grid ready, we proceed to apply inverse Fourier transformation to get our time-domain signal.

10. Design a code section that can convert the physical layer grid to a time-domain waveform given by the design parameters.
    a. Hint: The IFFT is computed per OFDM symbol.

We should have gotten a one-dimensional array of time-domain samples. Sections of these samples must be copied and appended in the so-called cyclic prefix insertion procedure.

11. Design a code section that can insert cyclic prefix into the time-domain waveform given by the design parameters.
    a. Hint: Depending on numerology and cyclic prefix mode, some symbols in specific time domain positions might have a higher number of samples.

Finally, up-conversion to RF frequencies can be performed to our newly constructed NR waveform.

12. (Optional) Design a code section that can modulate the time-domain waveform to the carrier frequency given by the design parameters.
    a. Hint: There are two different sampling frequencies to consider into the simulation, the sampling frequency to modulate at the carrier frequency, and the sampling frequency on which the baseband signal is built.

References

[1] Dahlman, Erik, Stefan Parkvall, and Johan Skold. 4G: LTE/LTE-advanced for mobile broadband. Academic press, 2013.

[2] 5G NR: The next generation wireless access technology. Academic Press, 2020.

[3] 3GPP TS 38.211 version 17.1.0 Release 17. Physical channels and modulation. 2022. Available online: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/17.01.00_60/ts_138211v170100p.pdf

[4] 3GPP TS 38.213 version 17.1.0 Release 17. Physical layer procedures for control. 2022. Available online: https://www.etsi.org/deliver/etsi_ts/138200_138299/138213/17.01.00_60/ts_138213v170100p.pdf

[5] 3GPP TS 38.101-1 version 17.5.0 Release 17. Physical layer procedures for control. 2022. Available online: https://www.etsi.org/deliver/etsi_ts/138100_138199/13810101/17.05.00_60/ts_13810101v170500p.pdf